Potential Landing Sites for Chandrayaan-2 Lander in Southern Hemisphere of Moon

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Introduction: The second moon mission of ISRO will comprise of an Orbiter craft and a Lander craft containing a Rover.The prime objective of Chandrayaan-2 mission is to design, realize and deploy a Lunar Lander-Rover, capable of soft landing on a specified lunar site and deploy a Rover to carry out in-situ analysis [1] . Lander is to be de-orbited from 100 km circular orbit and has to descend to the moon surface at the identified site using the liquid engines for braking. Landing site plays a key role in the success of soft landing for the Chandrayaan-2 Lander The Chandrayaan-2 Lander is planned to perform soft landing at the south polar region of the moon between 65° to 90° latitudes. Landing sites identification is one of the major challenges in any landing mission; they are normally selected on the basis of technical and scientific criteria. The technical criteria include safe landing (Hazard free area) and local mobility (global and local slope) and operational constraints (Earth visibility and Sun illumination, temperature and accuracies of the landing instruments and shadows due to local and global terrain). The scientific criteria include the surface composition, local geology and environments.

Landing Site Identification: The major hazards of importance are sopes, boulders / craters and shadows. Slope can be derived either from Digital Elevation Model (DEM) or from optical imagery using shades, whereas boulders and craters can be extracted from images through image processing techniques. With the current Lander design, hazards are defined as slopes steeper than 15° and surface features (e.g. boulders) higher than 32 cm. The Lander must also touch down on terrain which is not in shadow. Sun Illumination period at a particular site on moon's surface is the function of the sun's elevation variation at the corresponding latitude due to lunar rotation. The area of interest for identifying landing sites was initially started between 85-90 degree latitudes on both poles and the results were not so encouraging with respect to the landing ellipse of 16kmx10km [2] and the fact that though polar sites can extend the mission life due to large sunlit period and continuous radio link visibility, there are certain disadvantages associated with polar sites because of extreme conditions of local slope variations, boulders distribution , long shadows due to lesser elevation of sun, communication and sun blockage due to local slopes. These limitations can affect the Lander operation. Keeping the landing ellipse requirement and visibility (earth & moon) requirements , the earlier study was extended to the latitude limits of 65-90 degrees and longitude limit as near side of the moon.

Characterization of the Hazards: Based on Chandrayaan-1 TMC Polar mosaic, Kaguya Image, LROC-WAC image, LOLA DEM (**Figure-1)**, slope and shadow analysis of nearly 3500 polar images, two landing areas (SLS54 and ALS01) with landing ellipse of 32 km x 11 km are selected. The hazard Map generated using slope (>15°) and shadow (for one full year) is shown in **Figure**-2. **Figure-3** shows the two locations while **Figure-4** shows the one of the landing ellipses (SLS-54) and corresponding DEM. Further, the landing site analysis for the two landing ellipses has been performed using the 0.45 m resolution LRO NAC stereo images and derived DEM data. The following criteria were used to final landing site selection for safe landing.

- Slope less than 15 deg.
- Boulders less than 0.5 meter.
- Crater and boulder distribution.
- Sunlit for at least 14 days.
- Visible to Earth for Radio communication (i.e. on the near side).
- Local terrain features such that they don't shadow the site for long durations

Results & Conclusions: Using the above engineering constrains of Lander, 02 landing areas are further analysed and final coordinates for landing are derived based on the hazard free locations. The details of the selenographic coordinates of the two sites are provided in Table-1. The overview of the area and NAC image at 0.45m with corresponding hazard map of SLS-54 location is illutrated in F**igure-5** and **Figure-6** respectively. These sites are part of South Polar Aitken (SPA) basin which contain great scientific importance for study of surface composition and geology.

Table 1 Details of Potential Landing Site (32 km x 11 km landing ellipse)

SL. No.	Landing Site	Latitude	Longitude
1	SLS54 (Prime Site)	70.90267 S	22.78110 E
2	ALS01 (Alternate Site)	67.874064 S	18.46947 W

Future Work: These sites will be further characterized for detecting hazards (boulders) up to 32cm before

landing using Orbital High resolution Camera (OHRC) onboard Chandrayaan-2 Orbiter.

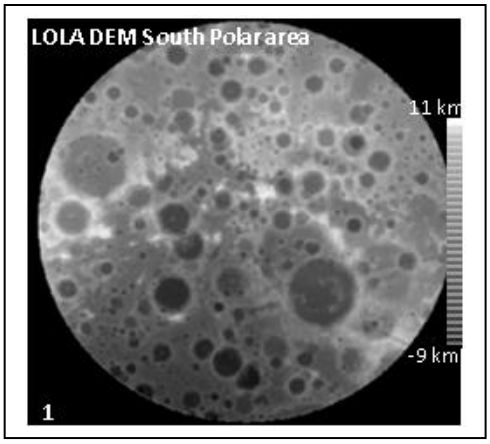

Figure-1 LOLA DEM used for LS identification

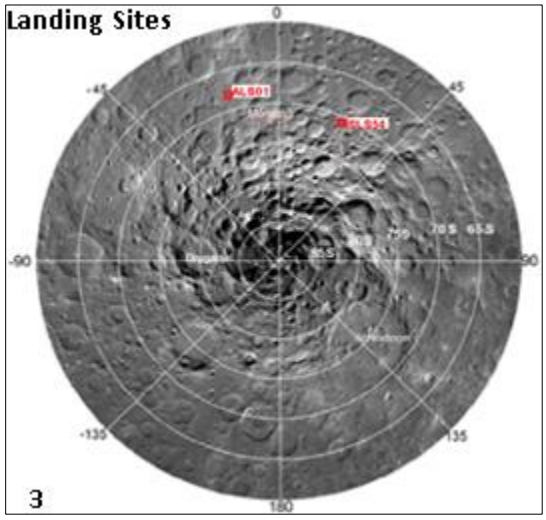

Figure-3 Landing Sites SLS54 & ALS01 over South Polar Mosaic (LRO WAC) image

Figure-5: Overview of SLS54

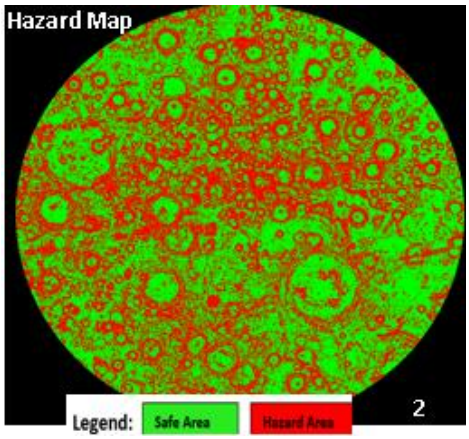

Figure-2 Hazard Map using Slope and shadow for South Polar region

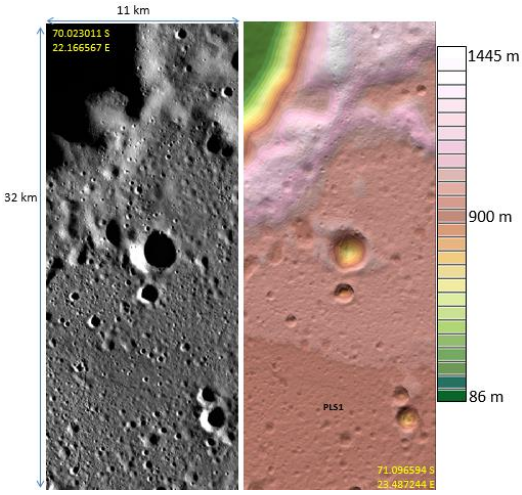

Figure-4 Overview of SLS54 Landing Ellipse and corresponding DEM (Topography)

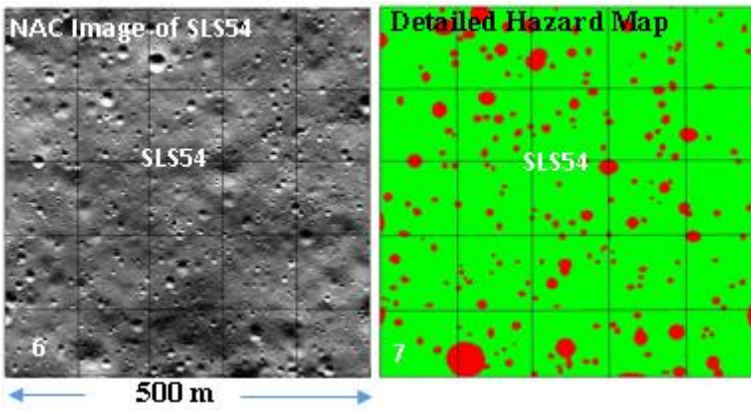

Figure-6: Hazard Map for 0.5 Sq km area around SLS54

References: 1. Landing Site for Chandrayaan-2 mission - A study; ISRO-ISAC-Ch2-PR-2434; **2.** Study of Potential Landing Sites on Lunar South Polar area for Chandrayaan-2 Lander,Abstract # 1351, 46th LPSC-2015; **3.** https://www.lroc.asu.edu **4**. http://www.kaguya.jaxa.jp